Modeling Block Copolymer Interactions with Biomimetic Membranes

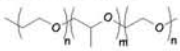
S. P. Adiga, P. Zapol, and M. A. Firestone
Materials Science Division, Argonne National Laboratory

Motivation

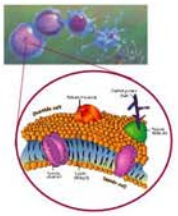
Association of amphiphilic di- and triblock copolymers with biomimetic membranes results in versatile novel materials with enormous potential in many areas of bionanotechnology. The molecular architecture and concentration of block copolymers along with environmental variables such as temperature and pH provide means to tune these structures for desired applications and also allow for designing signal-responsive materials. Understanding interaction between block copolymers and lipid bilayers is crucial for applications in nanomedicine. MD simulations are used to explore the effect of molecular architecture and concentration on the phase behavior of these materials.

Repair of disrupted cellular structures

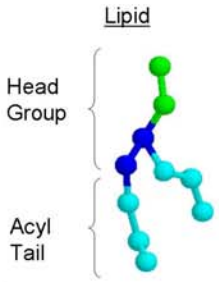
Repair of defects in biomembranes by administration of macromolecules



PEO-PPO-PEO Triblock copolymers



Coarse-Grained Model for Lipid-Polymer System



- Small groups of atoms are represented by single interaction sites
- DMPC lipid molecule: total ten beads of three different types.
- Block copolymers: hydrophobic and hydrophillic beads (range 20-120 beads).

Effect of Diblock Concentration and PEO Length on Interlamellar Spacing

PEO layer thickness from scaling laws:

$$H = a_{PEO}^{5/3} N_{PEO} \left(\frac{c}{A}\right)^{1/3}$$

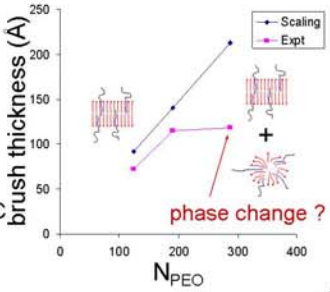
c – mol% of diblock copolymers

a_{PEO} – repeat length of PEO

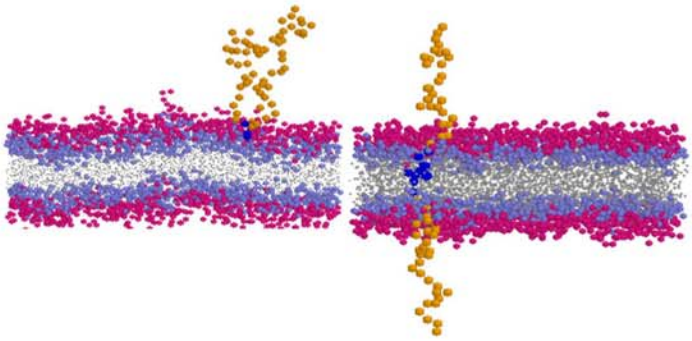
N_{PEO} - # repeats in PEO block

A – area per lipid molecule in DMPC

- **predict degree of insertion and structural change**



What is the Minimum Hydrophobic Segment Length for Triblock Insertion?



Harpoon (3 beads) Insertion (12 beads)

- MD simulations: A hydrophobic segment of ≥ 12 CG beads (36 PPO units) spans across the bilayer. The elastic stretching energy is compensated by hydrophobic interactions.

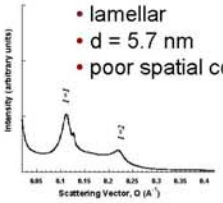
Impact:

- MD simulation and SAXS results explain why triblocks of PPO block length below 30 units seal defects in lipid bilayers.
- Defect sealing these pores promotes repair of membrane structure, leading to applications in healing of cell membranes.

X-Ray Scattering

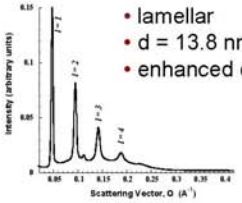
SAXS results suggest that PEO – PPO – PEO triblocks with a PPO block < 30 repeat units are in a harpoon configuration in DMPC bilayers – the PPO block is not long enough to span across bilayer.

- lamellar
- d = 5.7 nm
- poor spatial coherence



A membrane sealer

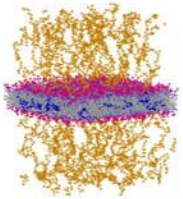
- lamellar
- d = 13.8 nm
- enhanced ordering



A robust nanostructure

Future Work

- MD simulations and mean-field calculations will be used to investigate how polymer concentration and chain length control lateral phase segregation in di- and triblock-lipid systems.
- MD simulations will be used to investigate the dependence of phase transition on the architecture and concentration of copolymers, as well as on temperature.
- This work is a critical first step in developing an approach to design of soft nanoscale architectures with desired functional properties.



Firestone, M.A.; Wolf, A. C.; Seifert, S., Biomacromolecules (2005), 6, 2678-2687.

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This work was supported by the U.S. Department of Energy, Basic Energy Sciences, under contract W-31-109-ENG-38.

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